(4)

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 May 2003 (30.05.2003)

PCT

(10) International Publication Number
WO 03/044894 A1

(51) International Patent Classification[7]: H01Q 7/08, 11/12

(21) International Application Number: PCT/IL02/00934

(22) International Filing Date: 21 November 2002 (21.11.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/331,726 21 November 2001 (21.11.2001) US
60/334,934 4 December 2001 (04.12.2001) US

(71) Applicant (*for all designated States except US*): **BROADSAT TECHNOLOGIES INC.** [US/US]; 1201 Market Street, Suite 1600, Wilmington, DE 19801 (US).

(72) **Inventor; and**
(75) **Inventor/Applicant** (*for US only*): **KEREN, Hanan** [IL/IL]; P.O. Box 753, 44 106 Kfar Saba (IL).

(74) **Agent: G. E. EHRLICH (1995) LTD.**; 28 Bezalel Street, 52 521 Ramat Gan (IL).

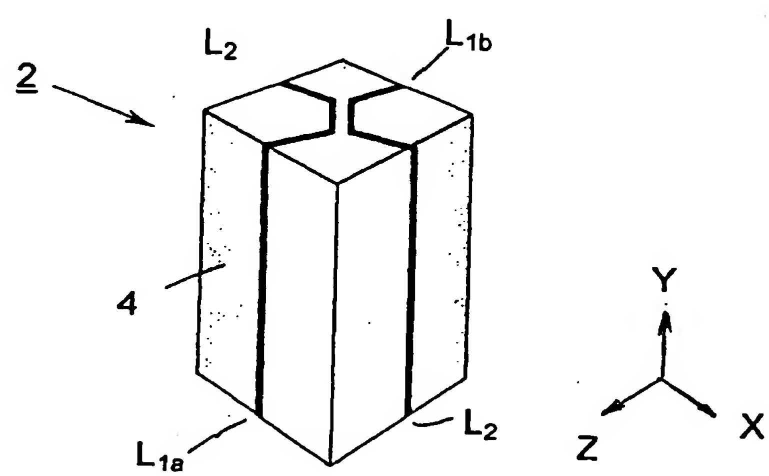
(81) **Designated States** (*national*): AE, AG, AL, AM, AT (utility model), AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ (utility model), CZ, DE (utility model), DE, DK (utility model), DK, DM, DZ, EC, EE (utility model), EE, ES, FI (utility model), FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SI, SK (utility model), SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) **Designated States** (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published:**
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) **Title:** ANTENNA ASSEMBLIES FOR WIRELESS COMMUNICATION DEVICES




**(57) Abstract:** An antenna assembly (2) for a wireless communication device including a first electrically conductive loop (L1) in a first plane, a second electrically conductive loop (L2) in a second plane orthogonal to the first plane, and a block of a solid dielectric material (4) enclosed by the two loops. The described antenna assembly has isotropic properties and produces a balanced antenna circuit enabling the SAR (Specific Absorption Rate) to be substantially reduced, and the battery life time to be substantially increased, in comparison to standard monopole or dipole type antennas commonly used in standard cellular telephones or other wireless communication devices.

WO 03/044894 A1

# ANTENNA ASSEMBLIES FOR WIRELESS COMMUNICATION DEVICES

## FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to antenna assemblies for wireless communication devices. The invention is particularly useful for cellular telephone communication devices and is, therefore, described below with respect to this application.

Great concern has been expressed that the magnetic component of the near-field radiation, which penetrates the user's head and causes thermal heating within the brain soft tissues due to induced eddy currents, could have a deleterious effect on the user, particularly over the long term. The electric components of the near-field radiation, which does not penetrate the user's head due to skin conductivity, does not have a deleterious effect on the user. Many techniques have been proposed to shield the user's head from the antenna, or for otherwise distancing the user's head from the antenna, since the radiation absorbed varies inversely to an inordinate degree with respect to this distance.

Moreover, the signal strength at which the cellular phone operates, and its antenna radiation pattern in space, not only affect the near-field radiation produced by the cellular phone, but also affect the usable period of the battery supply before recharging or replacement is required.

It would therefore be desirable to provide an antenna assembly which enables the cellular phone to be operated with better communication quality and less power, not only to reduce the near-field radiation produced by the cellular phone, but also to increase the usable period of the battery power supply before requiring recharging or replacement.

## OBJECTS AND SUMMARY OF THE INVENTION

An object of the present invention is to provide an antenna assembly for use with wireless communication devices in general and with cellular phones in particular, which enables the communication device to be operated with reduced near-field radiation, as well as better communication quality and lower battery power consumption, thereby permitting longer periods of use before requiring recharging or replacement.

According to a broad aspect of the present invention, an antenna assembly is provided a two-terminal balanced antenna assembly for a transceiver of a wireless communication device, comprising: a first electrically-conductive loop in a first plane; a second electrically-conductive loop in a second plane orthogonal to the first plane; and a solid dielectric core; the first and second electrically-conductive loops being connected in series with a common feed point connection, to provide a two-terminal balanced antenna assembly having reduced electromagnetic field radiation from the body of a transceiver when attached thereto in comparison to a monopole antenna of comparable gain.

Such an antenna assembly has isotropic properties, i.e., it is capable of transmitting and receiving signals in all directions. Therefore, it is less sensitive to the specific orientation of the antenna assembly and, thereby, enables the cellular phone, or other wireless communication device with which the antenna is used, to be operated with lower near-field signal strength without interruption in the transmission or reception due to the orientation of the antenna assembly at any particular time. By thus lowering the signal strength for operation of the cellular phone, the near-field radiation absorbed by the user is also reduced. In addition, the period of time during which the battery power supply can be used is increased before recharging or replacement is required.

According to further features of the antenna assembly described herein as preferred embodiments, the first and second electrically-conductive loops are located and electrically connected such that: one-half of the first loop is in the first plane and is connected at one end to a first feed point connection; the second loop is

fully in the second plane orthogonal to the first plane and is electrically connected at one end to the opposite end of said one-half of the first loop and the remaining one-half of the first loop is in the first plane and is electrically connected between the opposite end of the second loop and a second feed point connection.

In one described preferred embodiment, each of the loops is of a length equal to one-half the wavelength of a predetermined frequency within the operating frequency band of the antenna assembly, such that the antenna assembly is of one full wavelength. In a second described embodiment, each of the loops is of a length equal to one-quarter wavelength of a predetermined frequency within the operating frequency band of the antenna assembly, such that the antenna assembly is of a one-half wavelength.

In one preferred embodiment described herein, each of the loops is of rectangular configuration, more particularly of square configuration, and is constituted of an electrical conductor of flat cross-section. It will be appreciated that the antenna assembly could be of other configurations (e.g., circular), and constituted of electrical conductors of other cross-sections (e.g., circular).

In the preferred embodiments of the invention described below, the first and second loops of the antenna assembly enclose a cubical block of a solid dielectric material. The solid dielectric material is preferably one selected from the group of aluminum oxide, aluminum nitride, silicon nitride, zirconium oxide and a ferroelectrical dielectric. Particularly preferred materials are: aluminum oxide having a dielectric constant of in the range of 8.2 – 10.1; aluminum nitride and/or silicon nitride having a dielectric constant of about 9.9; the glass-ceramic Macor having a dielectric constant of about 5.9; Mullite having a dielectric constant of about 6.0, Zirconia having a dielectric constant in the range of 28 – 29, Vespel having a dielectric constant of about 13.5, and Kynar (PVDF) having a dielectric constant of about 8.0. However, other materials having similar dielectric characteristics may be used.

Further features and advantages of the invention will be apparent from the descriptions and technical discussions contained herein.

## BRIEF DESCRIPTION OF THE DRAWINGS

**Figure 1.** View from above, illustrating one form of antenna assembly constructed in accordance with the present invention.

**Figure 2.** View from below of the antenna assembly illustrated in Figure 1.

**Figure 3.** Illustrates a further antenna assembly constructed in accordance with the present invention.

**Figure 4.** Shows a circuit diagram illustrating one example of an electrical circuit that may be used for connecting the antenna assembly to the wireless communication equipment with which it is used.

## DESCRIPTION OF PREFERRED EMBODIMENTS

Reference is first made to Figs. 1 and 2, pictorially illustrating, from different viewing points, one form of antenna assembly constructed in accordance with the present invention. As shown in Figs. 1 and 2, the antenna assembly, therein generally designated 2, comprises a block of dielectric material for supporting a first loop in one plane, and a second loop in a second plane orthogonal to the first plane. In the example illustrated in Figs. 1 and 2, the first loop is constituted of two half-loops $L_{1a}$, $L_{1b}$ supported in the YZ plane (Fig. 2); whereas the second loop is constituted of a single full loop $L_2$ and is supported in the XY plane (Fig. 2). Both loops are connected in series with a common feed point connection defined by feed points $FP_1$, $FP_2$ (Fig. 2).

More particularly, in the example illustrated in Figs. 1 and 2, the dielectric material 4 is in the form of a hexahedron (cube). Thus, each of the half-loops $L_{1a}$, $L_{1b}$ of the first loop is of a semi-rectangle configuration; whereas the full second loop $L_2$ is of a rectangle configuration.

As will also be seen, particularly from Fig. 2, the two loops are located and electrically connected such that half-loop $L_{1a}$ is in the YZ plane and is connected at one end to feed-point connection $FP_1$; the second loop $L_2$ is fully in the XY plane and is electrically connected at one end to the opposite end of half-loop $L_{1a}$; and half-loop $L_{1b}$ is in the YZ plane and is electrically connected between the opposite end of loop $L_2$ and the second feed-point connection $FP_2$.

Preferably, each of the loops, namely the two half-loops $L_{1a}$, $L_{1b}$ taken together and the full loop $L_2$, is equal to one-half the wavelength of the predetermined frequency within the operative frequency band of the antenna assembly, such that the antenna assembly is a full wavelength antenna.

However, each of the loops may be of a length equal to one-quarter the wavelength of the predetermined frequency such that the antenna assembly would be a one-half wavelength antenna.

As shown in Figs. 1 and 2, the electrical conductor of the two loops is of a flat cross-section and is applied over the outer surface of the cubical dielectric body 4.

Fig. 3 illustrates a further embodiment, wherein the two loops, ($L_{1a}$, $L_{1b}$ and $L_2$, respectively) are made of electrically-conductive strips of flat cross-section, and are embedded, or otherwise covered, by the body of dielectric material. This antenna layout includes room for a balancing capacitor ($C_B$) to reduce the influence of user objects on the antenna characteristics.

Fig. 4 illustrates one example of an equivalent circuit that may be used for connecting the illustrated antenna assembly as described above to wireless communication equipment having a characteristic impedance of 50 ohm. The balancing capacitor $C_B$ keeps the antenna characteristics from being influenced by user objects, such as the human hand or the head. For example, $C_B$ may be in the range of about 3·5 pF. The value of the tuning capacitor $C_T$, may also be in the range of 3·5 pF, and the value the matching capacitor $C_M$ may be in the range of 3 – 10 pF. The value of the impedance Z in the illustrated antenna assembly may be computed as follows, in terms of the skin effect resistance together with the radiation resistance ($R_S$):

$$\frac{I}{Z} = j\omega C_M + \frac{I}{R_s + j(\omega L - \frac{i}{\omega C_T})} =$$

$$= \frac{R_S}{{R_S}^2 + [\omega L - \frac{I}{\omega C_T})^2} + j\left[\omega C_M - \frac{\omega L - \frac{I}{\omega C_T}}{{R_S}^2 + (\omega L - \frac{I}{\omega C_T})^2}\right]$$

THE 50Ω MATCHING BOUNDARY CONDITIONS

$$C_M = (1/\omega) \bullet (\frac{\omega L - \frac{I}{\omega C_T}}{{R_S}^2 + (\omega L - \frac{I}{\omega C_T})^2}) = \frac{\sqrt{R_S(50 - R_S)}}{(R_S^2 + 50R_S - R_S^2)\omega} = \frac{\sqrt{R_S(50 - R_S)}}{50 \bullet R_S \bullet \omega}$$

$$\frac{I}{50}=\frac{Rs}{R_S^{\,2}+(\omega L-\frac{I}{\omega C_T})^2} \Rightarrow \omega L-\frac{I}{\omega C_T}=\sqrt{Rs(50-R_S)}$$

$$Q=\frac{\omega L}{R_S} \Rightarrow \frac{I}{\omega C_T}=\omega L-\sqrt{R_S(50-R_S)}=Q\cdot R_S-\sqrt{R_S(50-R_S)}$$

$$C_T=\frac{1}{\omega(QRs-\sqrt{R_S(50-R_S)}}$$

**Helix Monopole and Double Helix Dipole operating frequency:**

$f \approx C / L$

$L = (\pi \times D \times N + H)$

Where:

$f$ = antenna operating frequency
$C$ = speed of light (= $3x10^{10}$ cm/sec)
$L$ = length of the helix antenna wire
$D$ = helix diameter

$N$ = number of turns

$H$ = height of Helix

$\pi = 3.1416$

**Dilex operating frequency:**

$f \approx C / (L \times \sqrt{\varepsilon})$

$L = 4 \times (H + W)$

Where:

f = antenna operating frequency
C = speed of light (= $3 \times 10^{10}$ cm/sec)
L = length of the Dilex antenna wire
H = dielectric height

W = dielectric width

ε = dielectric constant

## TECHNICAL DISCUSSION

The following discussion will be helpful in understanding the operation and advantages of the antenna described above.

Both the near-field and the far-field components of the Electro-Magnetic (EM) field of a dipole antenna much smaller than a wavelength are set forth in the following equations, as appearing on page 498 of the book "Fields and Waves in Modern Radio" by Simon Ramo and John R. Whinnery, second edition, (page 498):

$$H_\phi = \frac{I_o h}{4\pi} e^{jkr} \left[ \frac{jk}{r} + \frac{1}{r^2} \right] \sin\phi$$
$$Er = \frac{I_o h}{4\pi} e^{-jkr} \left[ \frac{2\eta}{r^2} + \frac{2}{j\omega\varepsilon r^3} \right] \cos\phi \qquad (1)$$
$$E\phi = \frac{I_o h}{4\pi} e^{-jkr} \left[ \frac{j\omega\mu}{r} + \right] \frac{1}{j\omega e r^3} + \frac{\eta}{r^2} \sin\phi$$

These equations comply with both the standard dipole antenna of the cellular handset and the antenna described above, as the dimensions of both kinds

of antennas (order of 1 cm) are much smaller than the RF (Radio Frequency) wavelength of 30 cm in air at 900 MHz of the cellular frequency band. Thus, the EM fields of both dipole and loop antennas can well be approximated by vectorial summation of very small dipole elements.

The near-field magnetic component, $H\phi$ in the above equations is predominantly responsible for the RF power deposition in a form of thermal heating within the human brain. The physical phenomena responsible for this brain heating is the induced eddy currents within the human brain tissue as a result of the time varying magnetic field $H\phi$.

The time varying electric components in the near field, $E\theta$ and $Er$, in the above equations, cause thermal heating only for the face skin as these EM components are shortened and blocked from penetrating the face skin due to the electrical conductance of the human tissues.

In regard to the far-field EM radiation pattern in both the transmit mode and the receive mode, the standard dipole antenna is of an omni-directional radiation pattern around the antenna long axis, while the loop antenna is of a more directive pattern. Thus the loop antennas will show an inferior communication performance when not directed optimally either toward the transmitting cellular base station or toward the direction where the received radiation is reflected toward the loop antenna.

Because of the directivity behavior in the loop antenna pattern, the antenna described herein is designed with two loops at 90° to each other to alleviate loop pattern directivity. Moreover the architecture of the antenna described herein is designed in a way that assures minimal coupling and balanced RF behavior for the two orthogonal loops of the antenna.

The dielectric material in the core of the described antenna enables the antenna size to be reduced, as the minimum needed antenna conductor length for high enough antenna radiation resistance is inversely proportional to the square root of the material dielectric constant.

The average RF transmitted power is reduced significantly in this antenna pattern and thus the transmitted RF power to the human brain is also reduced indirectly on the average.

A standard cellphone helix or whip antenna essentially functions as a dipole arrangement, in which the antenna acts as one half of the dipole, and the body of the phone as the other half. In contrast the antenna described above with reference to Figs. 1 – 4, being in the form of a two-orthogonal-loops antenna wound on a dielectric core, reduces substantially the radio frequency radiation from the phone body by virtue of its balanced antenna circuit being thus isolated from the cellphone body.

The described antenna is electrically small and therefore experiences a reduced radial electric field component. In comparison to a dipole or monopole type element, such as a helical whip antenna commonly used in mobile phone handsets, the described antenna produces a lower radial E-field, and consequently, a lower total E-field in the proximity of the element. The described antenna concept exploits the possibility of drastically reduced SAR (Specific Absorption Rate) and a longer battery lifetime for the cellular handset, in comparison to monopole or dipole type antennas.

To achieve this performance, the electrical specifications for the final radio frequency stage of the cellular handset phones should match the balanced antenna design. This balanced antenna design will imply, in theory, that loading effects due to human handling are minimal. In a realistic situation, in which the user is holding the mobile handset, lower RF transmitted power is required for maintaining the cellular communication quality at the same quality of service, resulting in a longer battery lifetime for the cellular handset.

In all the tested cases for various cellphone manufacturers, all using the standard antenna, it was found that the peak SAR from mobile phone handsets occurs adjacent to the body of the mobile phone. In all of these instances, the antenna described above offers the potential to reduce such radiation and therefore to lower the peak SAR.

The described antenna design could be optimized for reduction of the SAR to the human brain from the cellphone body ($W_{Body}$) by a factor of 10 relative to the performance of existing cellular handsets, as follows: In the case of an unbalanced standard antenna design, where the antenna acts as one half of the dipole and the

body of the phone as the other half cellphone, the running current in the antenna ($I_{Std\ Ant}$) is equal to the running current in the cellphone body ($I_{Body}$). In the case of the above-described balanced antenna, where the cellphone body is isolated from the antenna circuit, the running current in the antenna ($I_{new\ Ant}$) is higher by the square-root of the quality factor (Q) of the antenna circuit than the running current in the cellphone body ($I_{Body}$).

Since that the SAR from the cellphone antenna ($A_{Antenna}$) and from the cellphone body ($W_{Body}$) is proportional to the square of the current, the reduction in the SAR with the new antenna is obtained from the maximum possible Q factor for cellular antenna circuit needed to support up to 10% bandwidth ($\Delta\omega$) around the mid-band frequency ($\omega_0$), as derived from the following equations:

$$\omega_0/\Delta\omega = 10$$

$$Q = \omega_0/\Delta\omega$$

$$(W_{Antenna} / W_{Body})_{New\ Ant} / (W_{Antenna} / W_{Body})_{Std\ Ant} = Q = 10$$

An additional benefit, when radiation occurs predominantly from the antenna circuit as with the new antenna, rather than the mobile handset body, is that loading effects due to handling are minimal. This gives the potential for improved antenna gain, in a realistic situation in which the user is holding the mobile handset. Thus lower RF transmitted power is required for maintaining the cellular communication quality at the same grade of service, resulting in a longer battery lifetime for the cellular handset.

While the present invention has been described with respect to several preferred embodiments, it will be appreciated that these are set forth merely for purposes of example, and that many other variations and applications of the invention may be made.

WHAT IS CLAIMED IS:

1. A two-terminal balanced antenna assembly for a transceiver of a wireless communication device, comprising: a first electrically-conductive loop in a first plane; a second electrically-conductive loop in a second plane orthogonal to said first plane; and a solid dielectric core; said first and second electrically-conductive loops being connected in series with a common feed point connection, to provide a two-terminal balanced antenna assembly having reduced electromagnetic field radiation from the body of a transceiver when attached thereto in comparison to a monopole antenna of comparable gain.

2. The antenna assembly according to Claim 1, wherein said first and second electrically-conductive loops are located and electrically connected such that: one-half of said first loop is in said first plane and is connected at one end to a first feed point connection; said second loop is fully in said second plane orthogonal to said first plane and is electrically connected at one end to the opposite end of said one-half of the first loop; and the remaining one-half of said first loop is in said first plane and is electrically-connected between the opposite end of said second loop and a second feed point connection.

3. The antenna assembly according to Claim 1, wherein each of said loops is of a length equal to one-half the wavelength of a predetermined frequency within the operative frequency band of the antenna assembly, such that the antenna assembly is of one full wavelength.

4. The antenna assembly according to Claim 1, wherein each of said loops is of a length equal to one-quarter wavelength of a predetermined frequency within the operative frequency band of the antenna assembly, such that the antenna assembly is of a one-half wavelength.

5. The antenna assembly according to Claim 1, wherein each of said loops is of rectangular configuration.

6. The antenna assembly according to Claim 1, wherein each of said loops is of square configuration.

7. The antenna assembly according to Claim 1, wherein each of said loops is constituted of an electrical conductor of flat cross-section.

8. The antenna assembly according to Claim 1, wherein said solid dielectric material is selected from the group of aluminum oxide, aluminum nitride, silicon nitride, zirconium oxide, and a ferroelectric dielectric.

9. The antenna assembly according to Claim 1, wherein said solid dielectric material is a glass-ceramic, Mullite, Zirconia, Vespel, or PVDF.

10. An antenna assembly for a wireless communication device, comprising: a first electrically-conductive loop constituted of two half-loops both disposed in a first plane; and a second electrically-conductive loop in a second plane orthogonal to said first plane and located between said two half loops; said first and second loops being connected together in series with a common feed point.

11. The antenna assembly according to Claim 10, wherein: one half-loop of said first loop is in said first plane and is connected at one end to a first feed point connection; said second loop is fully in said second plane orthogonal to said first plane and is electrically connected at one end to the opposite end of said one half-loop; and the other half-loop of said first loop is in said first plane and is electrically-connected between the opposite end of said second loop and a second feed point connection.

12. The antenna assembly according to Claim 10, wherein said first and second loops enclose a block of a solid dielectric material.

13. The antenna assembly according to Claim 10, wherein each of said loops is of a length equal to one-half the wavelength of a predetermined frequency within the operative frequency band of the antenna assembly, such that the antenna assembly is of a full wavelength.

14. The antenna assembly according to Claim 10, wherein each of said loops is of rectangular configuration.

15. The antenna assembly according to Claim 10, wherein each of said loops is of square configuration.

16. The antenna assembly according to Claim 10, wherein each of said loops is constituted of an electrical conductor of flat cross-section.

17. An antenna assembly for a wireless communication device, comprising: a first electrically-conductive loop in a first plane; and a second electrically-

conductive loop in a second plane orthogonal to said first plane; said first and second electrically-conductive loops being connected in series with a common feed point connection.

18. The antenna assembly according to Claim 17, wherein said first and second loops enclose a block of a solid dielectric material.

19. The antenna assembly according to Claim 17, wherein said first and second electrically-conductive loops are located and electrically connected such that:

one-half of said first loop is in said first plane and is connected at one end to a first feed point connection;

said second loop is fully in said second plane orthogonal to said first plane and is electrically connected at one end to the opposite end of said one-half of the first loop;

and the remaining one-half of said first loop is in said first plane and is electrically-connected between the opposite end of said second loop and a second feed point connection.

20. The antenna assembly according to Claim 17, wherein said solid dielectric material is selected from the group of aluminum oxide, aluminum nitride, silicon nitride, zirconium oxide, and a ferroelectric dielectric.

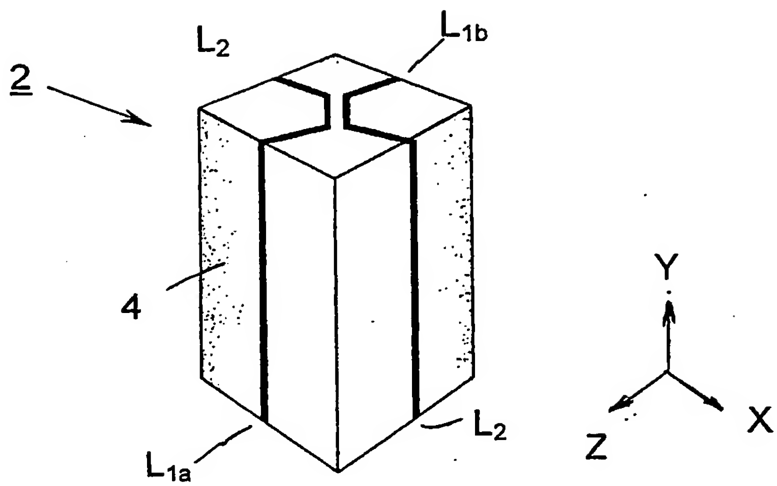



Fig. 1

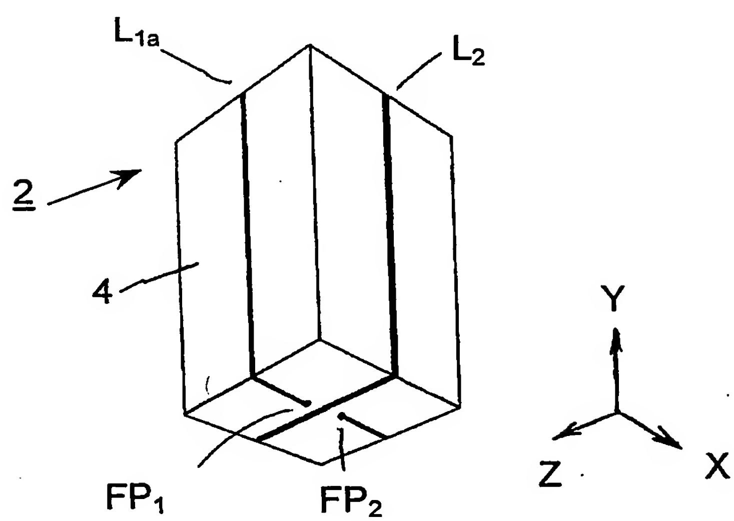



**Fig. 2**

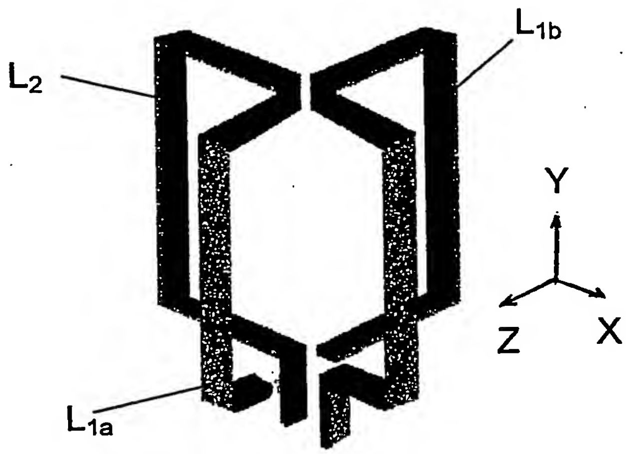



Fig. 3

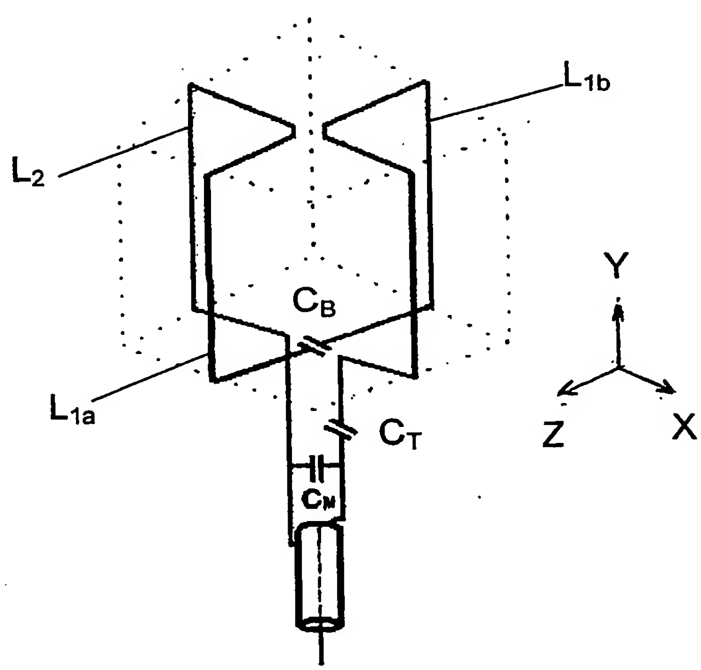



Fig. 4

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/IL02/00934

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(7) :HO1Q 7/08, 11/12
US CL : 343/741, 742, 866, 867, 788
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 343/741, 742, 866, 867, 788

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

none

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

BRS

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 6,014,107 A (WIESENFARTH) 11 January 2000 (11.01.2000), see entire document | 10-20 |
| A | US 6,014,111 A (JOHANNESSEN) 11 January 2000 (11.01.2000), see entire document | 1-20 |

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

| | |
|---|---|
| Date of the actual completion of the international search<br>07 FEBRUARY 2003 | Date of mailing of the international search report<br>28 MAR 2003 |
| Name and mailing address of the ISA/US<br>Commissioner of Patents and Trademarks<br>Box PCT<br>Washington, D.C. 20231<br>Facsimile No. (703) 305-3230 | Authorized officer<br>THO G. PHAN for Deborah P. Vega<br>Deborah P. Vega<br>Paralegal Specialist<br>Technology Center 2800<br>Telephone No. (703) 308-3051 |